BASIC ELECTRICITY AND ELECTRONICS

STUDENT HANDOUT

NO. 308

SUMMARY

PROGRESS CHECK

AND JOB PROGRAM

FOR MODULE 32-1

JUNE 1984

SUMMARY
LESSON 1

Hartley Oscillators

This lesson explains the operation of the Hartley oscillator, a type of
oscillator commonly used in electronic equipments. One application for
this oscillator is providing frequency injection for the mixer stage of
a superheterodyne radio receiver. When the oscillator is used in this way
it is called a local oscillator (LO). The Hartley circuit is also used
to provide a variable frequency in radio transmitters and signal generators.

There are two types of basic Hartley oscillators...series and shunt. Both
of these oscillators are discussed in subsequent paragraphs and comparable
AC circuit schematics are provided. The major advantage of a Hartley type
oscillator is that it provides good frequency stability over a wide
range of frequencies and produces a constant amplitude sine wave output.

Recall that one of the requirements of any oscillator is the necessity for an
in-phase (regenerative) feedback voltage. In order to assure that the regenera-
tive feedback is in phase with the input of the amplifying device, it is
necessary to effect a 360 degree phase shift within the oscillator circuit.
This is discussed in detail in subsequent paragraphs relating specifically to
the Hartley oscillator.

Remember that the function of an oscillator is to produce a constant amplitude
stable output signal. Recall also that unless the feedback is regenerative,
oscillations cannot be sustained. Since the purpose of feedback is to compen-
sate for internal power loss, it is obvious that when the feedback is exactly
in phase, less feedback is necessary to overcome circuit losses. A difference
of a few degrees in the phase of the feedback either way still enables the
circuit to oscillate. The amplitude of the necessary feedback required to
sustain oscillation, of course, is much less when the feedback is exactly in
phase. The schematic diagram shown in Figure 1 is the AC equivalent of a
Hartley type oscillator.

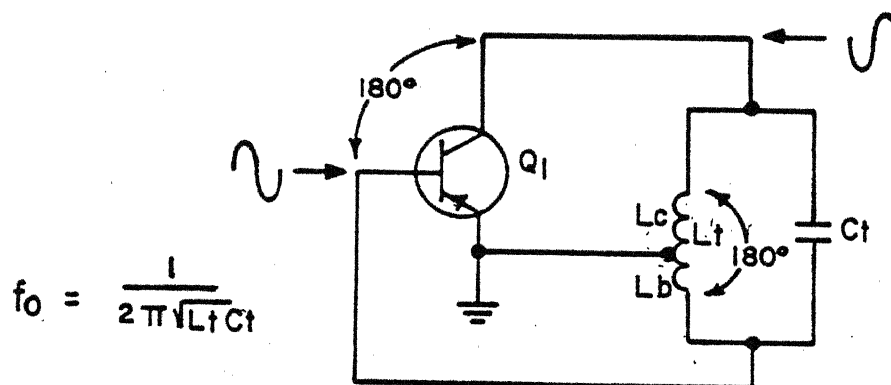$$f_o = \frac{1}{2\pi\sqrt{L_t C_t}}$$

Figure 1

AC EQUIVALENT-HARTLEY OSCILLATOR

Phase shift in the Hartley oscillator is accomplished in a similar way to
that of the Colpitts oscillator. If you do not recall how the Colpitts
functions, please refer to Module 22, Lesson 4. · The main difference between
the Hartley and the Colpitts is that the Hartley uses a tapped inductor
to provide the 180° phase shift, whereas the Colpitts uses a capacitive
voltage divider. In the Hartley type oscillator the tank circuit is excited
by the voltage from the collector of the transistor. Look at the schematic
and notice that the AC voltage at the bottom of the coil is 180° out-
of-phase with the AC collector voltage of the transistor. Waveforms are
shown on the schematic in order to help you understand the operation of the
oscillator more readily. In this instance,the inductance of the oscillator,
specifically L_t, may be considered as an inductive voltage divider. Notice
that the inductance in this example is center tapped. In actual practice the
tap may be somewhat off center. The actual location of the tap depends on the
amount of feedback which is required. Even though the tap may be somewhat off-
center, sufficient feedback can still be provided to maintain oscillation in
the circuit.

Two simplified AC equivalent schematics are shown in Figure 2. These sche-
matics are for the Hartley and the Armstrong oscillator.
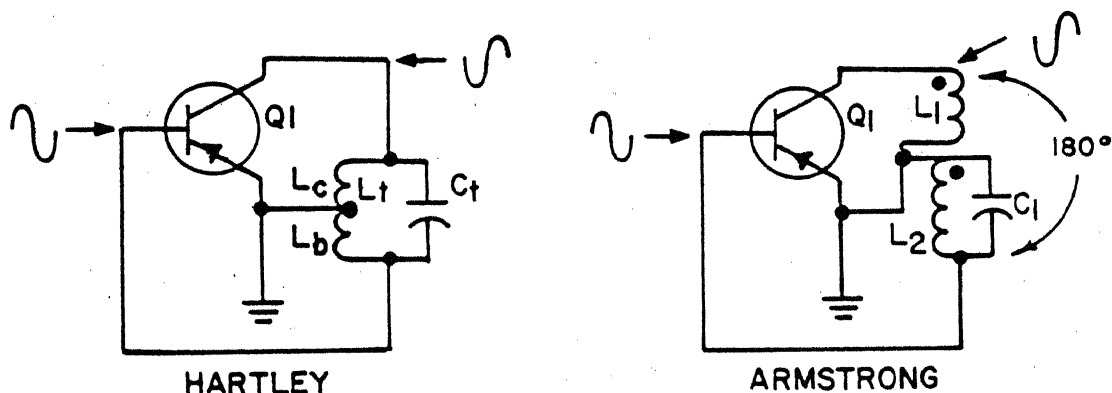

HARTLEY   **ARMSTRONG**

Figure 2

AC OSCILLATOR EQUIVALENTS

In the case of the Armstrong oscillator, feedback is accomplished by trans-
former action. Notice that the output signal from the collector of Q1 is
transformer coupled from L1 to L2 and back to the base of the transistor.
This in itself results in a 180° phase shift. The additional phase shift is
accomplished by the action of the transistor. Phasing dots have been shown
on the schematic to emphasize the phase shift that occurs in the transformer.
If the connections of L1 and L2 are reversed, the circuit will stop

oscillating. Study the Hartley schematic shown in the Figure and notice that the primary of the transformer is designated as L_c and the secondary section of the transformer is designated as L_b. Although these coils have a common point, mutual coupling still exists between them. Current which flows through L_c induces a voltage across L_b and produces transformer coupling action comparable to the transformer coupling action of the Armstrong circuit. This type of coupling action is often referred to as an "autotransformer action".

Remember that the two major classifications of Hartley oscillators are series and shunt-fed oscillators. Recall also that one of the characteristics of all oscillators is that the amplifier section of the oscillator must be forward biased in order to provide amplification. The schematic shown in Figure 3 is that of a series-fed Hartley oscillator circuit.
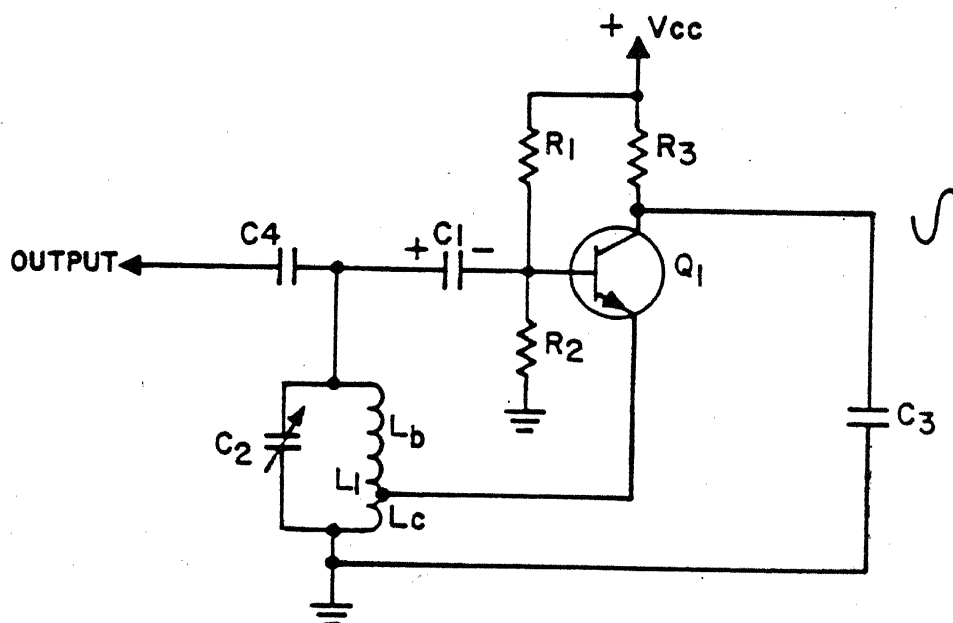

Figure 3

SERIES-FED HARTLEY OSCILLATOR

Examine the schematic and notice that resistors R1 and R2 provide the forward bias for Q1. Current flowing from ground to VCC places the forward bias of Q1 at approximately 0.6 volt positive. Remember that a forward bias is necessary in order for the transistor to conduct and oscillation to begin. Transistor current then flows from ground through the tank coil L_c, Q1, R3 and then back to VCC. This creates a magnetic field around coil L_c which induces a voltage into coil L_b. The polarity of the voltage across L_b
es the forward bias of the transistor to increase, as does the conduction
le transistor. Transistor conduction then follows the voltage across
ank.   At the same time, the induced voltage in L_b and L_c
oscillations in the tank circuit. The alternate charging and discharging
causes an exchange of energy from the capacitor's electric field to
nductor's magnetic field. This interaction between the tank capacitor

and inductor is sometimes called the "flywheel effect".

The tank circuit has now been shocked into oscillation by the inductive action of L_c and L_b. Remember that once the tank begins to oscillate it will continue to oscillate as long as sufficient regenerative feedback is provided to overcome tank and circuit losses. In this case the tank signal is inverted by Q1 and coupled to the bottom of L_c where the tank circuit inverts the signal another 180°. This provides the positive regenerative feedback necessary to keep the tank circuit oscillating. Remember that the tank continues to oscillate as long as sufficient regenerative feedback is provided to compensate for tank and circuit power losses. You can see from this explanation that an oscillator is basically a tank circuit, an amplifier and a regenerative feedback path.

Refer again to the Hartley schematic shown in Figure 3. When the oscillator commences to oscillate, the base-emitter voltage of Q1 drops to less than 0.6 volt. In some cases, this voltage may even be negative. The reason for this change in voltage is the charge on capacitor C1. In other words, the capacitor develops a voltage across it which opposes the transistor forward bias established by R1 and R2. As you know, this reduces the forward bias of Q1. Refer again to to the schematic shown in Figure 3 and notice that the current passes through coil L_c. Because the DC current flow through coil segment L_c increases the voltage drop across the coil, in some respects the coil acts like a series resistor. Remember that increasing the resistance of a tank coil reduces the Q of the coil and the tank circuit. There is one undesirable effect associated with this and that is that the tank bandwidth increases causing the oscillator to operate at a frequency other than that which was originally intended or desired.

Frequency stability of an oscillator circuit depends on the Q of the oscillator tank. With a high Q, good stability is provided, whereas a low Q tank produces less stability for the oscillator circuit. A method commonly used to improve the frequency stability of an oscillator circuit is to remove the DC current from the tank circuit. This is accomplished by moving the ground from the bottom of the tank to the emitter of Q1.
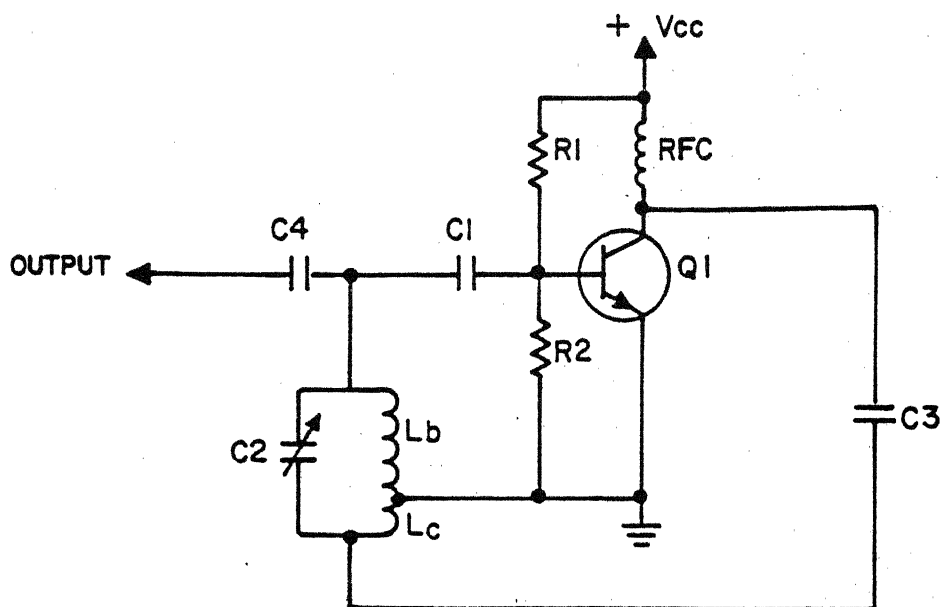
The modified circuit is shown in Figure 4.

Figure 4

SHUNT-FED HARTLEY OSCILLATOR

This is also the schematic of a shunt fed Hartley oscillator. This type
of oscillator has better frequency stability. To further improve the perform-
ance of the oscillator, an RFC is used instead of a resistor for the collector
load. Because this device has little DC resistance and provides a large
AC reactance it keeps the oscillating signal from entering the power supply
source and increases the DC collector working voltage. You undoubtedly
remember that AC entering the power supply source could cause interference
with other circuits using the same power supply as a voltage source. Using
the RFC as a collector load is not unique to the shunt-type Hartley oscillator.
The RFC could also be used with a series-fed oscillator circuit.

With series and shunt-fed Hartley oscillators, the transistors that are
used may be either PNP, or NPN. These circuits may also be represented
schematically in a different way.

Two additional examples of Hartley type oscillator schematics are shown
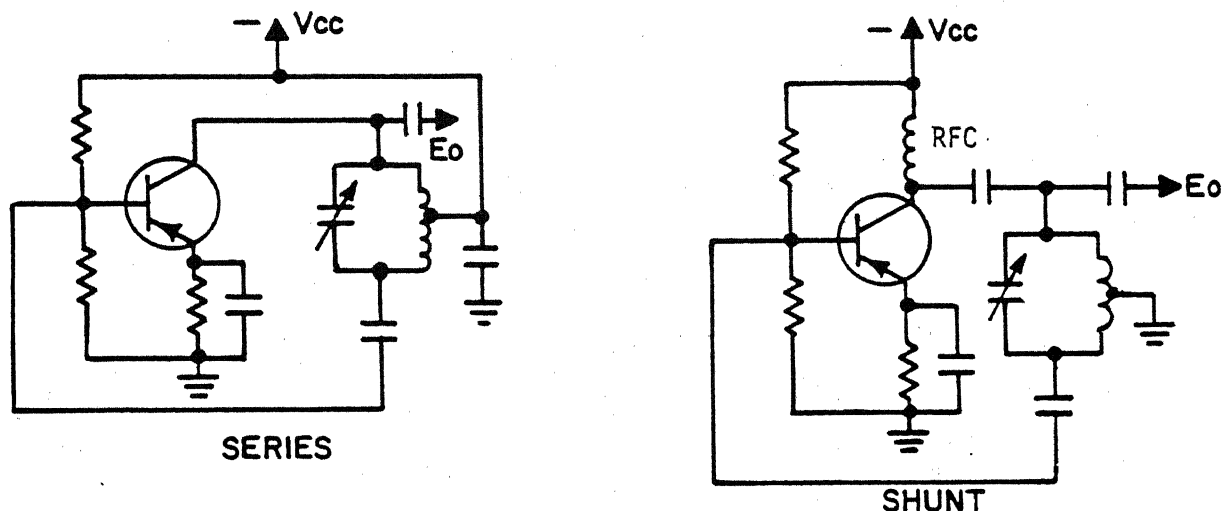in Figure 5.

Figure 5

HARTLEY OSCILLATOR SCHEMATICS

As an exercise, trace the DC current paths from ground through the transistor
to VCC in order to verify the circuit names. One way of identifying the
Hartley type oscillator circuit from other oscillator circuits is to determine
whether the tank coil has been tapped. After you determine that the tank
coil is tapped, you can easily determine whether the oscillator is series
or shunt by tracing the current flow through the transistor. When the tank
circuit is in parallel, or in shunt with the transistor, the circuit is
a shunt-fed Hartley oscillator. When the transistor current passes through
the tank coil, the circuit is a series-fed Hartley oscillator.

It is often necessary to determine the oscillating frequency of an oscillator.
You may have used an oscilloscope to make this determination. Because
the oscilloscope does not provide the accuracy required, a frequency counter
is now the standard piece of test equipment used for determining frequency.
The digital frequency counter is more accurate because it minimizes the
loading of the oscillator circuit and provides a direct digital read-out of
the oscillator frequency. The digital frequency counter is crystal controlled
and is accurate to 1 part in 10^8 or 1 hertz in 100 MHz. One such frequency
counter which you will have an opportunity to use in the job program is
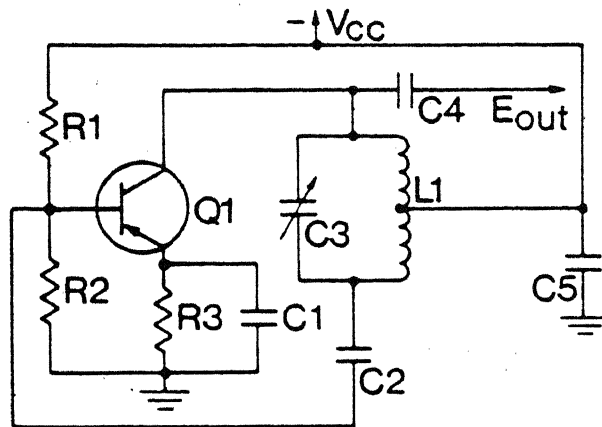the AN/USM-207.

AT THIS POINT YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL
SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY
ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER
PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO
THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY
WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE
LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL
MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR,
UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 1

Hartley Oscillators

1. One function of an oscillator is to

    a. change DC to AC.
    b. change AC to DC.
    c. increase AC output.
    d. decrease DC output.

2. Oscillator feedback must be _____ in order for the oscillator to continue oscillating.

    a. out of phase
    b. degenerative
    c. regenerative
    d. neutralized

3. A Hartley-type oscillator provides

    a. little input regulation and constant output.
    b. good   frequency stability and a constant amplitude sine-wave output.
    c. little frequency stability with a constant sine-wave output.
    d. average frequency stability with reduced output amplitude.

4. A Hartley oscillator tank circuit provides a _____ for the feedback voltage

    a. damped output
    b. 90° phase shift
    c. 180° phase shift
    d. 360° phase shift

5. 360° of feedback in a Hartley oscillator is accomplished as a result of

    a. tank circuit and amplifier inversion.
    b. the internal action of Q1.
    c. the tank capacitor and inductor.
   d. flywheel effect of the tank.

6. A high tank Q in an oscillator circuit

    a. has no effect on frequency stability.
    b. results in less frequency stability.
    c. results in greater frequency stability.
    d. ~educes the output voltage.

7. The Q of a coil in a tank circuit depends on the ratio of

    a. XL/R.
    b. R/XL.
    c. R/XC.
    d. RX/L.

8. The tank circuit in a Hartley oscillator accomplishes both

    a. frequency selection and phase cancellation.
    b. frequency selection and phase inversion.
    c. frequency inversion and phase selection.
    d. frequency inversion and phase cancellation.

9. One advantage of using a radio frequency choke (RFC) in a shunt type
    Hartley oscillator is that the choke

    a. has the advantage of little current drain.
    b. is more stable due to an increased resistance.
    c. provides a large AC impedance and little DC resistance.
    d. provides a small AC impedance and large DC resistance.

10. A distinguishing characteristic of Hartley type oscillators is the

    a. use of NPN transistors.
    b. use of PNP transistors.
    c. variable frequency of the oscillator tank.
    d. tank coil tap.

11. The schematic shown below is that of a

        a. Colpitts oscillator.
        b. Armstrong oscillator.
        c. shunt-fed Hartley oscillator.
        d. series-fed Hartley oscillator.

12. The schematic shown below is that of a
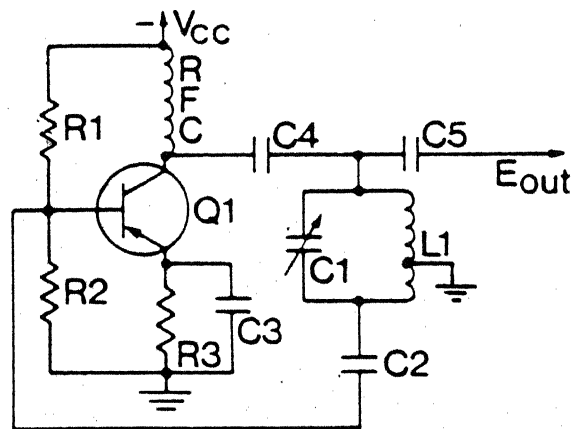
        a. series-fed Hartley oscillator.
        b. shunt-fed Hartley oscillator.
        c. variable frequency Armstrong oscillator.
        d. Colpitts oscillator.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU
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INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT
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CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

JOB PROGRAM
FOR
LESSON I

Hartley Oscillators

INTRODUCTION

This Job Program is designed to permit you to check the frequency of a
Hartley oscillator using the AN/USM-207 frequency counter. Figure 1
will indicate the position of the various controls necessary to complete
these measurements. All other front panel controls have not been shown
since they are concerned with other measurements which the counter is
capable of performing.

SAFETY PRECAUTIONS:

Observe all standard safety precautions. Beware of all open and exposed
connections; an energized circuit may have dangerous voltages present.

EQUIPMENT AND MATERIALS

1. NIDA 205 Transceiver Trainer
2. AN/USM-207 Frequency Counter
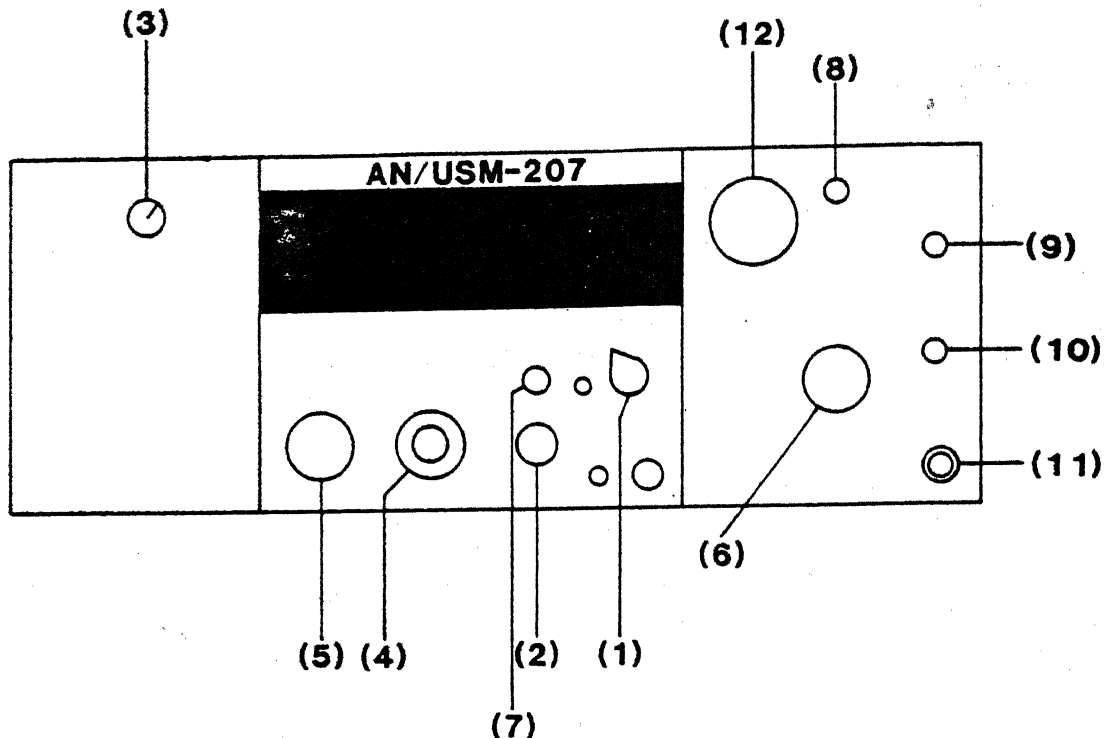3. BNC-Alligator Clip Cable (1)

AN/USM-207

Figure 1

PROCEDURES:

DO NOT USE A DMM FOR MEASURING PN JUNCTION RESISTANCE. NORMALLY A DMM DOES NOT HAVE SUFFICIENT VOLTAGE TO FORWARD BIAS A TRANSISTOR JUNCTION.

1. Plug in and energize the AN/USM-207 frequency counter. To energize, turn the power switch (1) to STBY and observe that both the power on lamp and the oven lamp are lit. Allow at least five minutes for warm up, then turn the power switch (1) to TRACK. Notice that once the frequency counter is turned on, it cannot be accidentally turned off. To turn the frequency counter off, you must push the small pushbutton on the left of the switch.

2. Set the DISPLAY control (2) one-quarter turn from its maximum CCW position. The DISPLAY control varies the length of time that the count is displayed.

3. Set the SENSITIVITY switch (3) to the PLUG-IN position. The SENSITIVITY switch selects the source of the input signal (test or plug-in) and the amount that the signal is attenuated if the signal is applied to the "FREQ A" jack.

4. Set the TIME BASE switch (4 black knob) to the GATE TIME (SEC-1) to 10^4. The TIME BASE switch selects the unit of measurement (kHz or MHz) and the position of the decimal point.

5. Set FUNCTION switch (5) to the FREQ position. The FUNCTION switch selects the mode of operation (frequency or period).

6. The purpose of RESET switch (7) is to return the display to zero in order to start another count.

7. On the CV-1921/USM-207 FREQUENCY CONVERTER, set the FREQUENCY TUNING-MC switch (6) to 100. Notice that this switch selects frequencies from 100 to 500 MHz in increments of 50 MHz. You must know the approximate frequency applied before using this converter.

8. Set the DIRECT-HETERODYNE switch (8) to HETERODYNE. This position of the switch will mix the input frequency with 100 MHz and display the difference between the two frequencies. By adding the displayed frequency to 100 MHz, you have the frequency applied to the input jack.

9. Set the ATTENUATOR switches (9) and (10) to the 10V MAX position. These switches determine the amount that the signal applied to the converter will be attenuated.

10. (11) is the input connector to the CV-1921/USM-207 frequency converter.

11. (12) is the converter meter and registers the strength of the signal being applied to the counter. If the meter is positioned in the red or low green the signal is _not_ strong enough to drive the counter.

12. Connect the BNC-BNC coaxial cable from the L.O. OUTPUT jack on the front panel of the NIDA 205 Transceiver to the INPUT jack on the CV-1921/USM-207 Frequency Converter. Study Figure 2 and notice that the oscillator in the transceiver is a Hartley type circuit.

FREQUENCY CONVERTER
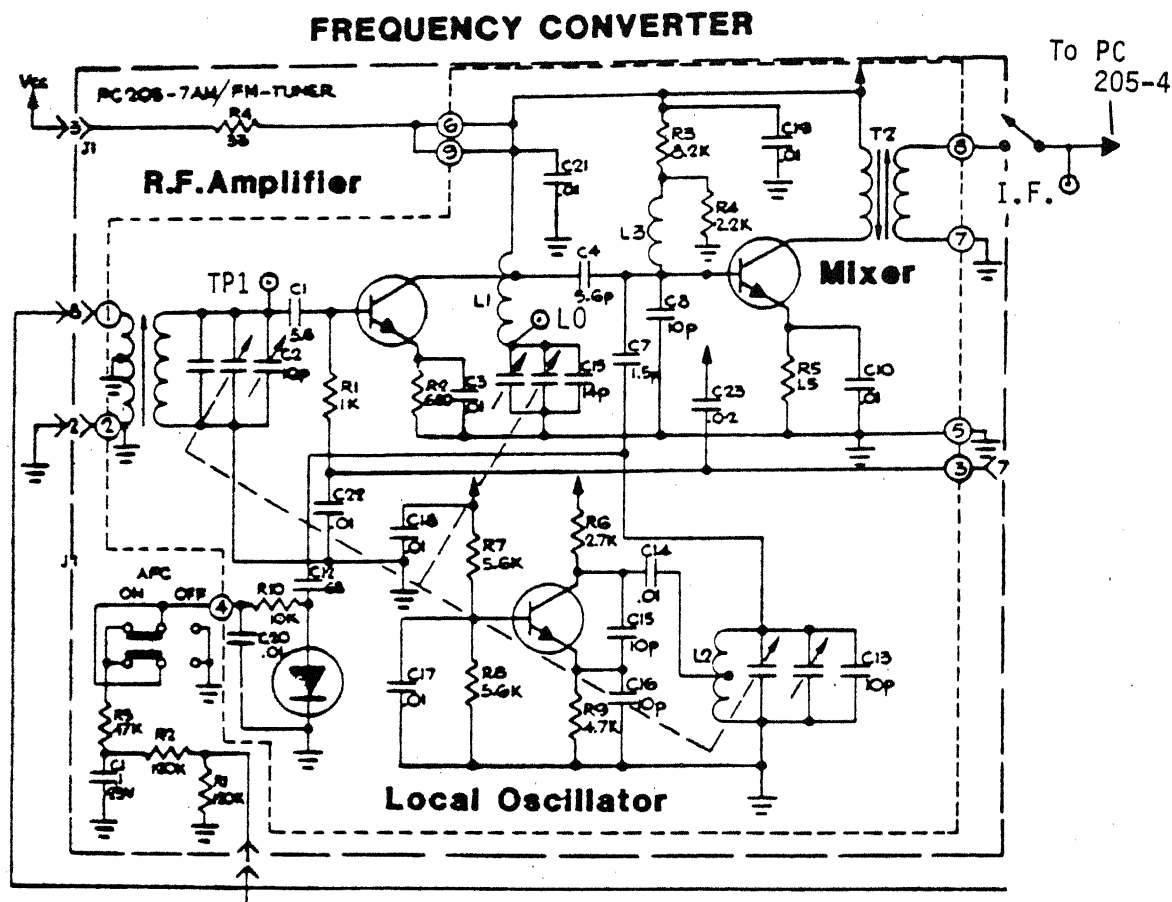
Figure 2

13. Set the frequency dial on the NIDA 205 Transceiver to 108 MHz.

14. Plug in and energize the NIDA 205 Transceiver. A reading should appear on the frequency counter display. If a reading does _not_ appear, set the attenuator switches on the frequency converter to 0.3V position.

15. If the frequency counter jumps to the 25 MHz range you are overdriving the frequency counter. Move the lower attenuator switch on the frequency converter to the right to reduce the amplitude of the signal feeding the counter.

NOTE: When you studied FM IF amplifiers you learned that a common IF was 10.7
       MHz. The Local Oscillator frequency in this receiver is tracking above
       the incoming RF frequency. As an example of this, assume that you are
       receiving a station transmitting on 104.0 MHz FM. The Local Oscillator
       is therefore operating at a frequency of 114.7 MHz or 10.7 MHz above
       the station frequency. Since the frequency converter in the frequency
       counter is producing 100 MHz and is mixing with the Local Oscillator
       frequency of 114.7 MHz, then the frequency counter should indicate the
       difference between the two frequencies or 14.7 MHz.

16.   From the information given in steps #8, #13 and the above note, answer
       the following questions.

       a.   What is the frequency shown on the frequency counter? _____ MH

       b.   What is the frequency of the Local Oscillator? _____ MH

       c.   What is the frequency of your FM station? _____ MH

17.   Notice in step 16c above that this is very close to the setting of the
       frequency dial on the NIDA 205 Transceiver.

18.   Move the TIME BASE switch (4-black knob) CCW step by step and notice the
       position of the decimal point. The more numbers you have to the right
       the decimal point, the more accurate will be your reading.

NOTE: Go through your own selection of frequency settings on the dial of the
       NIDA 205 Transceiver and do the calculations in step #16 until you
       completely understand the operations for frequency measurements using
       the AN/USM-207 frequency counter.

You have now completed the Job Program on the Hartley oscillator. As you noticed in Figure 2, the Local Oscillator on the NIDA 205 Transceiver is a Hartley oscillator. You have seen how the frequency of the oscillator was changed so that the IF would remain the same. You have also learned how to measure frequency using the AN/USM-207 frequency counter. This same counter is used on many ships and stations throughout the U.S. Navy.

CHECK YOUR RESPONSES TO THIS JOB PROGRAM WITH THE ANSWER SHEET. IF YOUR RESPONSES AGREE WITH THE ANSWER SHEET, YOU MAY TAKE THE LESSON TEST. IF YOUR RESPONSES DO NOT AGREE OR IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THIS JOB PROGRAM, REVIEW THE PROCEDURES OF THIS JOB PROGRAM, ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS, OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR. UNTIL YOUR RESPONSES DO AGREE.

A.S. (J.P.)

ANSWER SHEET
FOR
JOB PROGRAM
LESSON 1

Hartley Oscillators

16. a. 18.56 MHz
    b. 118.56 MHz
    c. 107.86 MHz

ANSWER SHEET FOR

PROGRESS CHECK

LESSON 1

Hartley Oscillators

QUESTION No.   CORRECT ANSWER

1.   a.

2.   c.

3.   b.

4.   c.

5.   a.

6.   c.

7.   a.

8.   b.

9.   c.

10.   d.

11.   d.

12.   b.